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MORPHOLOGICAL DIVERSITY AND AGRONOMIC EVALUATION OF PROMISCUOUS VARIETIES OF SOYABEAN

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ABSTRACT

Promiscuous varieties have the potential to increase soyabean (*Glycine max* (L.) Merrill) production of resource poor farmers who cannot afford artificial inoculum. Some varieties grown by smallholders are known to be promiscuous but their yields are reported to have declined overtime, yet researchers questions their purity. It is suspected that these varieties are made up of mixtures of genotypes with varying nodulation capacities. A study was carried out to quantify diversity in two promiscuous varieties, Local, and A&11 using morphological markers to initiate mass selection to reconstitute the original varieties. Eight Phenotipic Groups (PGs) were identified in the variety Local mainly based on days to flowering, growth habit and flower colour, whereas in the variety A&11, days to flowering, number of primary branches, and response to rust infection revealed seven PGs. A second study evaluated the agronomic performance of the PGs in comparison with a specifically nodulating commercial variety Storm. Five of the PGs identified in A711 had significantly (P<0.01) higher grain yield than the commercial standard. All eight PGs identified in Local yielded the same as the commercial standard.

Key Words: Genotype, *Glycine max*, nitrogen fixation, nodulation

RÉSUMÉ

Les espèces à reproduction aisée possèdenet le potentiel d'augmenter la production de grain de soja [*Glycine max* (L.) Merrill] au sein d'agriculteurs à ressources médiocres qui ne peuvent pas se permettre les couts de l'inoculation artificielle. Certaines espèces cultivées par de petits planteurs sont connues pour leurs facilité de reproduction mais il a été noté que leur rendement se déteriore avec le temps alors que les chercheurs mettent question leur pureté. Des suspicions existent selons lesquelles ces variétés seraient composées de mélanges de génotypes à capacité de nodulation variable. Une étude aété entreprise en vue de pouvoir quantifier la diversité au sein de 2 variétés à reproduction facile, Locale et A&11 en utilisant les marqueurs morphologiques pour initier la séléction de masse dans le but de reconstitüer les variétés originales. 8 groupes phénotypiques (PGs) étaient identifiés dans lka variété Locale en se basant principalement sur les jours à la froraison, habitude de croissance et couleur de la fleur tandis que dans la variété A&11, les jours à la floraison, nombre de branches et réaction à l'infection de rouille révélaient 7 PGs. Une 2ème étude a évalué la performance agronomique des PGs en comparaison avec une variété commerciale à nodulation spécifique ; Storm. 5PGs identifiés au sein de A&11 avaient un rendement de grain significativement (P<0.01) élevé par rapport au standard commercial. Tous les 8 PGs au sein de Locale ont produit un rendement similaire à celui du standard commercial.

Mots Clés: Génotype, *Glycine max*, fixation d'azote, nodulation

INTRODUCTION

Soyabean (*Glycine max* [L.] Merill) production in Zimbabwe is mainly confined to the large-scale commercial farming sector which has easy access to commercial *Rhizobium* inoculum required for nodulation. Naturally nodulating (promiscuous) varieties can nodulate without artificial inoculum. These can potentially increase soyabean production of resource poor farmers. According to Jahaveri (1994), access by smallholders to artificial inoculum is limited by lack of: (i) facilities to produce quality inoculum and distribute in many developing countries; (ii) appropriate facilities to store inoculum; (iii) education in the correct use of inoculum; and (iv) finance to carry out research in fields like selection to correct rhizobium species for various environments. Therefore, promiscious varieties provide an alternative option in soybean production to overcome these problems.

The yield of promiscuous varieties grown by smallholders in Zimbabwe has declined and researchers suspect existing varieties not to be pure due to observed variable agronomic performance. Available data suggests that there has been little improvement in soybean productivity amongst smallholders, inspite of intensive efforts to improve agronomic practices. Mabika and Mariga (1996) reported that the average yield of promiscuous varieties was 600 kg ha^{-1} in 1985/86 in the Zimbabwean smallholder sector and showed no improvement at 593 kg ha^{-1} in 1993/94. The agronomic characterisation of these promiscuous soyabean varieties is, therefore, considered an important activity that would facilitate their purification and promotion in the smallholder farming sector. Availability of uniform materials of the promiscuous varieties would facilitate better response in research plots and a field level.

Morphological diversity studies can indicate the possibility of selecting from within varieties to reconstitute an original variety or to develop new ones. This can be done using the mass selection method of plant breeding as outlined by Allard (1960), Singh (1983) and Poehlman and Sleper (1987). Mass selection has been used successfully in developing varieties in different crops around the world. Sharama (1992) gave an account of the varieties developed by mass selection in India and these include maize varieties *Jaunpur local*; *Tinpakhi; Bass*, T13; T19 and T41. In pearl millet varieties like *Bajra 207*; *Bajri*-28-15; LM-38-59 and COI were developed (Sharma, 1992) and there are examples in sorghum, mustard, cotton and peanut that can also be cited.

MATERIALS AND METHODS

Two studies, one on morphological diversity and another on field evaluation of phenotypic groups (PHs) were conducted during the period 2002 to 2004. Field experiments were carried out at Thornpark Farm (31° East, 17° 31" South) in the 2002/2003 and 2003/2004 rainy seasons. Fields are 1480 metres above sea level and soils are classified as 5E.2 on the Zimabwean system of Chromic Luvisol on the FAO system. Average rainfall experienced is 815 mm with reliable distribution over 19.2 rainy pentads. In both experiments, basal fertiliser was drill-applied at 150 kg ha-1 at planting as Cottonfert [N (5%): P_20 (17%): K_20 (10%); B (0.25%)].

Seed was planted at a depth of about 3 cm in fine seedbed prepared by ploughing with a tractor-drawn mould board plough followed by discing to fine tilth. Inter-row spacing was 0.45 m and 0.03 m within the row. Seed was not prior to planting. Planting irrigation of about 20 mm was applied to ensure maximum germination in each of the two experiments.

Morphological diversity studies in Local and A&11. Two promiscous varieties, Local and A711, and a commercial control, Soma were planted at Thornpark Farm, each in a plot measuring 135 m^2 at a density of 74 plants m^{-2}. Mass selection (Allard, 1960; Singh, 1983; and Poehlman and Sleper, 1987) was used to conduct the morphological diversity study. The method was modified to group identified plants into PGs; retain seed of the PGs for further testing and document information on the PGs. Tags with information on plant height, number of primary branches per plant, flower colour, growth habit, response to disease, leaf shape and pod colour were tied to individual plants within Local and A711. From these traits, a final set was selected for use in grouping the plants into PGs. Response to rust was measured as either tolerant or susceptible. Plants that resisted complete defoliation within two weeks of rust attack were considered tolerant and those that were completely defoliated within the two weeks were considered susceptible.

Tagged pants were harvested first and the information on tags used to group the plants into PGs. In Local, flower colour, days to onset of flowering and growth habit were used to group the plants whereas in A &11, flower colour, days onset of flowering, the number of primary branches per plant and response to rust diseases were used. Flowering times were assigned classes such that in Local, there were nine three-day interval classes and in A711, five one-day interval flowering classed due to less variability observed. In Local, 59 to 61 days after sowing (DAS) formed the first class, 62 to 64 DAS the second, 65 to 67 DAS the third, 68 to 70 DAS the fourth, 71 to 73 DAS the fifth, 74 to 76 DAS the sixth, 77to 79 DAS the seventh, 80 to 82 DAS the eighth and 83 to DAS 85 DAS the ninth. In A7111. 53 to 54 DAS formed the first class, 55 to 56 DAS the second, 57 to 58 DAS the third, 59 to 60 DAS the fourth and 61 to 62 DAS the fifth. Within each flowering class, the day that recorded the highest number of flowering plants was used to identify the group with respect to flowering. The established PGs were assigned names the described the traits unique to the group. Plants that were not selected in the selection plots were bulked.

Field evaluation of the Phenotypic Groups identified in the varieties Local and A711. Eight PGs in Local and five in A711 were planted in two separate trials in 2003/2004 in a preliminary evaluation of their agronomic performance. Plots were single rows of 5 m length planted 0.45 m apart with in-row spacing of 0.15 m. The study was laid in a completely randomised design. Plot size was limited by seed quantity available. Commercial variety Storm was used as the control in both trials. The following parameters were measured in each trial: (i) days to first emergence; (ii) days to first flowering; (iii) days to 95% physiological maturity; (iv) emerged plants per plot; (v) primary branches; (vi) pods per plant; (vii) three seeded pods; (viii) barren pods per plant; (ix) pod clearance; (x) weight of grain per plot and its moisture content; and (xi) plant height at maturity stage. Grain yield was reported at 12.5% moisture content.

RESULTS AND DISCUSSION

Results of the morphological diversity study showed that eight and seven PGs could be established from the promiscuous varieties Local and A711 (Table 1). The results are consistent with the phenotypic heteorgeneity reported by researches who have worked on promiscuous varieties in Zimbabwe. The variability was attributed to seed mixtures. Mixture could have arisen as a result of mutations as pointed out by Poehlman and Sleper (1987). Natural hybridasation could not possibly have caused variations such as the presence of determinate and indeterminate plant types in Local.

Days from emergence to onset of flowering varied from 61 to 82 in Local and 58 to 61 in A711 (Table 1). This was the most important differentiating trait in both varieties' PGs. The trait is also used to differentiate between soyabean varieties. Joshi and Jahaveri (1986) described the flowering times of the promiscuous varieties Magoye and Hernon 147, as 56 and 50 days, respectively. Thus heterogeneity in flowering times within a variety can be said to be an indication of mixtures of genotypes. In Local, growth habit was also an important trait. Tattersfield (1986) reported that most soyabean varieties were either indeterminate or determinate and the main difference between soybean varieties Storm and Solitaire was that the former is determinate and the later indeterminate (Seed Co, 2000). Local was described as indeterminate and the presence of determinate plants is an indication of contamination. There was good agreement between phenotypic groups on the basis of growth habit and dates to onset of flowering with later flowering plants being indeterminate and early ones determinate in Local (Table 1). This could be a result of gene linkage or pleiotropy although no work has been reported to that effect.

On evaluating the PGs, significant differences ($P<0.05$) were observed on the number of primary branches, plant height, and pod clearance in Local PGs (Table 2) and on days to first flowering, days to 95% physiological maturity and pod clearance

TABLE 1. The PGs identified in the promiscuous varieties Local and A711

Code	Phenotypic group	Hilum colour	Description of group
Phenotypic groups identified in the variety local			
1	LP61D	Cream	Selected from local, had purple flowers, were in the 61 days
2	LP63D	Cream	Selected from Local, had purple flowers, were in the 63 days to flowering group and had a determinate growth habit.
3	LP65D	Cream	Selected from Local, had purple flowers, were in the 65 days to flowering group and had a determinate growth habit.
4	LP681	Brown	Selected from Local, had purple flowers, were in the 68 days to flowering group and had an indeterminate growth habit.
5	LP711	Brown	Selected from Local, had purple flowers, were in the 71 days to flowering group and had an indeterminate growth habit.
6	LP751	Brown	Selected from Local, had purple flowers, were in the 75 days to flowering group and had an indeterminate growth habit.
7	LP791	Brown	Selected from Local, had purple flowers, were in the 79 days to flowering group and had an indeterminate growth habit.
8	LP821	Brown	Selected from Local, had purple flowers, were in the 82 days to flowering group and had an indeterminate growth habit.
Phenotypic Groups Identified in the variety A711			
1	AP582	Grey	Selected from A711, had Purple flowers, were in the 58 days to flowering group and had 2 primary branches.
2	AP583	Grey	Selected from A711, had purple flowers, were in the 58 days to flowering group and had 3 primary branches.
3	AP584	Grey	Selected from A711, had purple flowers, were in the 58 days to flowering group and had 4 primary branches.
4	AP614	Grey	Selected from A711, had purple flowers, were in the 61 days to flowering group and had 4 primary branches.
5	AP54V	Dark Brown	Selected from A711, had purple flowers, were in the 54 days to flowering group and had variable numbers of primary branches.
6	AP56V	Black	Selected from A711, had purple flowers, were in the 56 days to flowering group and had variable numbers of primary branches.
7	AP61RT	Brown	Selected from A711, had purple flowers, were in the 61 days to flowering, had variable numbers of primary branches and had some Rust Tolerance

TABLE 2. Field performance of PGs identified in the variety Local in comparison with a Seed Co. commercial variety storm

PG	DTF	DPM	NPB	Ht (cm)	PC (cm)	Grain yield (kg ha^{-1})
LP61D	72.0	117.0	5.5	83.0	14.0	1804
LP63D	56.0	117.0	6.0	69.0	20.0	1555
LP65D	62.0	120.0	4.0	83.0	25.0	2093
LP681	56.0	108.0	7.0	107.0	23.0	1977
LP711	70.0	122.0	6.0	104.0	22.0	1995
LP791	64.0	119.0	8.0	109.0	27.0	1817
LP821	70.0	114.0	7.0	81.0	12.0	1426
Storm	68.0	112.0	5.0	76.0	13.0	1168
Mean	63.8	115.8	6.3	92.1	19.9	1652
$LSD_{(0.05)}$	ns	ns	1.9	29.06.4	ns	ns
CV(%)	15.7	4.4	13.5	13.9	14.3	35.2

Key
PG - Phenotypic Group
NPB - Number of primary branches
Ht - Plant height at physiological maturity
PC - Pod clearance
DTF - Days to first flowering
DPM - Days to 95% physiological maturity
ns - not significant

in A &11 PGs (Table 3). There was no significant yield difference between the control and the Local PGs. This was due to high variability in the data as indicated by CV of 35%. As shown in Table 2, five of the PGs achieved yields approximating 2 t ha^{-1} indicating the potential of developing some good lines from Local. There were significant differences in grain yield (P<0.01) between Storm and the A711 PGs (Table 3). Three of the PGs AP61RT, AP582 and AP584 yielded between 2.5 and 3.3 t ha^{-1} and all were superior to Storm without nodulation. This yield level is in excess of the national average obtained for soybean production in Zimbabwe. The results obtained in the trials are consistent with those obtained by Khonje (1994) in Malawi, who reported specifically nodulating variety Geduld producing the same yield with the promiscuous variety *Magoye* under the same environmental conditions. The differences observed among the phenotypic groups and control variety, Storm, may be explained by differences in promiscuity levels as explained by Mwakalombe (1988), who worked with varieties Hernon 147 and Magoye. Since the site on which the trial was established was previously grown to maize, the *Rhizobium* levels might have been low as reported by Sanginga *et al.* (1996), who worked with the varieties TGX 1456-2E and TGX 1669 - 19F in Northern and Southern Guinea and detected low indigenous rhizobia levels on soils previously cropped with maize or other cereals but higher levels on soils with a history of soyabean.

Further evaluation of the PGs can lead to reconstitution of the originally released promiscuous varieties and the contaminating germplasm can be uses in crop improvement programmes. There is also need to confirm genetic differences among the PGs with promising yield performance as shown in Tables 2 and 3. Yields achieved are far in excess of the average of about 600 kg ha^{-1} achieved by smallholders in Zimbabwe (Mabika and Mariga, 1996). These low yields could have resulted from some of the materials failing to behave promiscuously and fix nitrogen possibly as a result of mixture with specific

TABLE 3. Field performance of PGs identified in the variety A711 in comparison with a Seed Commercial variety Storm

PG	DTF	DPM	NPB	Ht	PC	Gain yield ($kg\ ha^{-1}$)
AP582	62.0	116.0	6.0	75.0	18.0	2800
AP583	69.0	111.0	6.0	73.0	27.0	2151
AP584	55.0	123.0	6.0	78.0	20.0	3326
AP614	69.0	113.0	6.0	68.0	14.0	1680
AP61RT	68.0	120.0	5.0	76.0	23.0	2480
Storm	68.0	112.0	5.0	76.0	13.0	1195
Mean	65.2	115.8	5.7	74.3	19.2	2272
$LSD_{(0.05)}$	12.4	5.6	ns	ns	6.0	889
CV(%)	5.9	2.0	22.7	6.4	12.8	16.9

Key
PG - Phenotypic Group
NPB - Number of primary branches
Ht - Plant height at physiological maturity
PC - Pod clearance
DFT - Days to first flowering
DPM - Days to 95% physiological maturity
ns - not significant

varieties. This assertion is supported by a high requirements for inorganic fertiliser in soybean production on smallholder farms in Zimbabwe noted by Tsikisayi (1996) contrary to conventional wisdom that only low level of start-up fertiliser are required. If properly targeted in environments with indigenous *Rhizobia*, promiscuous varieties would require lower levels of inorganic fertilisers and their use would not only result in savings in fertiliser, but the lines identified in this study would also increase yield achieved by promiscuous varieties.

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